Effect of Harvesting to Various Merchantable Limits on Loblolly Pine Logging Residue

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Abstract

Regression equations are used to estimate dry weight and composition of logging residue remaining after harvesting a natural, uneven-age loblolly stand to various merchantable tops. Results indicate that if the sale trees were harvested to a 6-inch DIB top, 526 pounds of dry logging residue would remain for every dry ton of wood and bark removed. Logging the sale to a 4-inch top would reduce logging residue to 392 pounds per ton of wood and bark logged, and logging to a 2-inch top plus utilizing limbs ≥ 2 inches in diameter would leave only 200 pounds of residue per ton of wood and bark logged.

BECAUSE DEMANDS FOR WOOD are rapidly approaching projected supplies, forest industries are keenly interested in minimizing the amount of wood residues left after logging. But to utilize most or all of the tree, these industries must know what proportion of the biomass is residue and what proportions of the residue are wood, bark, and needles. This paper reports such information for an uneven-age, natural stand of loblolly pine (*Pinus taeda* L.) in central Alabama.

Prediction equations developed on an independent sample were used to determine the aboveground dry weight of a loblolly pine sawtimber sale and to estimate the weight and composition of logging residues if the sale were logged to different merchantable limits. The regression equations and residue data presented in this paper are applicable only to stands similar to the one sampled.

Procedure

Biomass prediction equations were developed from a stratified sample of 35 loblolly pine sawtimber trees. The equations were then demonstrated on 311 sawtimber trees marked for sale in a similar stand. The sample trees averaged 15.1 inches DBH and 61 feet to a 6-inch DIB merchantable top (Table 1).

After felling and limbing, the main stem of each sample tree was divided into merchantable saw logs (to a 6-inch DIB top) and pulpwood (6-inch to 2-inch DIB top). The crown was cut up, and branch material 2 inches or more in diameter, branch material less than 2.0 inches in diameter, and needles were weighed separately. The tip (2 inches to the top) of each stem was treated as branch material.

Table 1. — MEANS AND RANGES IN CHARACTERISTICS OF THE 35 LOBLOLLY PINE SAWTIMBER TREES SAMPLED FOR DEVELOPING PREDICTION EQUATIONS.

Item and unit of measure	Mean	Range
Diameter breast height (in.)	15.1	9.8 - 20.4
Total height (ft.)	87	63 -107
Height to 6-inch top (ft.)	61	40 - 81
Form class	80	72 - 86
Age (years)	42	31 - 48

Material in roots and in stumps to a height of 6 inches was ignored, and in this paper the terms total tree or total wood exclude roots and stumps. Green weights of the three crown components and pulpwood were determined in the field on a portable 300-pound scale. Merchantable saw logs were weighed individually at a nearby woodyard.

Moisture content of wood and bark in the main stem was determined from disks taken at each saw log bucking point and at the heights of 4- and 2-inch DIB. Moisture content of wood and bark in each crown component was determined from branch samples taken randomly from each branch category. A sample of needles was taken for determination of needle moisture content. Moisture content samples were ovendried to a constant weight at 103°C, and moisture content was calculated as a percentage of ovendry weight.

Percentages of bark in each tree component were determined on a weight basis from disk and cross section samples. Green weights were adjusted to ovendry weights on the basis of moisture content found in sample materials.

Regression equations were developed to predict dry weight of needles, wood, and bark in various tree components using DBH and merchantable height (height

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to 6-inch DIB or merchantable top) as the independent variables. Component weights were estimated with the normal volume equation:

$$Y = b_0 + b_1 D^2 MH \qquad [1]$$

Where: Y = dry weight of component in pounds
D = DBH in inches
MH = merchantable height in feet to 6-inch top.

Plottings of the data indicated a heterogeneous variance, thus the logarithmic form of the normal volume equation was used to make the variance more nearly homogeneous. The dry weight of each tree component was estimated using the equation:

$$\mathrm{Log}_{10} Y = b_0 + b_1 \mathrm{Log}_{10} D^2 MH \qquad [2]$$

Table 2. — FREQUENCY DISTRIBUTION OF LOBLOLLY PINE SALE TREES IN A NATURAL, CLOSED, UNEVEN-AGE STAND IN CENTRAL ALABAMA.

DBH class (in.)	Merchantable height in feet (6-in. top)									All heights
	17	25	33	41	49	57	65	73	81	
	(number)									
10										
11	2	4	7	10	17	2	3			45
12	2	1	8	19	14	12	7			63
13	1	2	6	15	13	17	2		1	57
14	1	2	4	6	13	9	3			38
15			1	4	12	7	3		1	28
16	1		1	4	4	8	2	4		24
17				3	6	3	5			17
18			1	2	7	1			1	12
19			1	2	3	1	6			13
20						4		1		5
21			1		2		3			6
22					1		2			3
Total										311

The equations were demonstrated on a loblolly pine timber sale in central Alabama in a stand similar to that sampled to develop the prediction equations. The sale consisted of 311 trees, 11 to 22 inches in diameter, and contained an estimated 50,458 board feet. The average DBH of the sale trees was 14 inches, and the average merchantable height was 49 feet (Table 2).

Estimated dry weights of the various tree components were summarized to indicate amounts of wood, bark, and needles utilized or left as residue by harvesting to four different merchantable limits: 1) saw logs only to a 6-inch DIB top; 2) saw logs to 6-inch DIB top plus pulpwood to 4-inch DIB top; 3) all stem material to a 2-inch DIB top; and 4) all stem material to a 2-inch DIB top plus all limbs ≧2.0 inches in diameter.

Results

Regression Equations

Eleven regression equations were developed in this study. Six of these equations predict the dry weight of stemwood and stembark to three different merchantable heights (6-, 4-, and 2-inch DIB), and five predict the dry weight of branchwood, branchbark, and needles in the crown.

The equations accounted for 95 to 98 percent of the variation associated with regression in the dry weight of stemwood and stembark, and for 74 to 84 percent of the variation in the dry weight of branchwood, branchbark, and needles (Table 3). Coefficients of variation show that bark dry weight of each tree component was considerably more variable than dry weight of wood. Of all components measured, dry weight of bark from branches ≧2.0 inches DOB varied most.

Tree Biomass

The average ovendry weights of sample trees 10 to 20 inches DBH and their component parts are shown in Table 4, together with the relative proportions of the components. The average weight of a complete tree

Table 3. — COEFFICIENTS OF DETERMINATION, STANDARD ERRORS, COEFFICIENTS OF VARIATION, AND REGRESSION EQUATIONS FOR ESTIMATING DRY WEIGHT OF VARIOUS TREE COMPONENTS FOR LOBLOLLY PINE TREES 10 TO 20 INCHES DBH.

Tree component	Regression equation[1]	Coefficient of determination (R)	Std. error of estimate	Coefficient of variation (%)
Stemwood to 6-in. DIB top	$\mathrm{Log}_{10}Y = -0.73110 + 0.91718\ \mathrm{Log}_{10}D^2MH$	0.98	0.0407	1.3
Stembark to 6-in. DIB top	$\mathrm{Log}_{10}Y = -1.04450 + 0.76746\ \mathrm{Log}_{10}D^2MH$	0.95	0.0511	2.4
Stemwood to 4-in. DIB top	$\mathrm{Log}_{10}Y = -0.53811 + 0.87570\ \mathrm{Log}_{10}D^2MH$	0.97	0.0446	1.5
Stembark to 4-in. DIB top	$\mathrm{Log}_{10}Y = -0.86476 + 0.72913\ \mathrm{Log}_{10}D^2MH$	0.95	0.0514	2.4
Stemwood to 2-in. DIB top	$\mathrm{Log}_{10}Y = -0.47771 + 0.86208\ \mathrm{Log}_{10}D^2MH$	0.97	0.0450	1.5
Stembark to 2-in. DIB top	$\mathrm{Log}_{10}Y = -0.80981 + 0.71689\ \mathrm{Log}_{10}D^2MH$	0.95	0.0509	2.4
All branchwood	$\mathrm{Log}_{10}Y = -2.20575 + 1.06509\ \mathrm{Log}_{10}D^2MH$	0.83	0.1443	6.6
All branchbark	$\mathrm{Log}_{10}Y = -1.76732 + 0.81100\ \mathrm{Log}_{10}D^2MH$	0.74	0.1438	9.2
Branchwood of branches ≧2.0 in. DOB	$\mathrm{Log}_{10}Y = -3.52801 + 1.32704\ \mathrm{Log}_{10}D^2MH$	0.84	0.1742	9.0
Branchbark of branches ≧2.0 in. DOB	$\mathrm{Log}_{10}Y = -3.36608 + 1.09905\ \mathrm{Log}_{10}D^2MH$	0.76	0.1873	16.3
Needles	$\mathrm{Log}_{10}Y = -1.58383 + 0.80387\ \mathrm{Log}_{10}D^2MH$	0.78	0.1273	7.4

[1] $\mathrm{Log}_{10}Y = b_0 + b_1 \mathrm{Log}_{10}D^2MH$

Where: Y = dry weight of components in pounds
D = diameter at breast height in inches
MH = merchantable height to 6-in. DIB top in feet

Table 4. — AVERAGE OVENDRY WEIGHT OF COMPLETE LOBLOLLY PINE TREES 10 TO 20 INCHES DBH AND THE PROPORTION OF COMPONENT PARTS IN THE NEEDLES, BRANCHES, AND MAIN STEM.

DBH class (in.)	Trees sampled	Weight				Proportion		
		Total	Needles	Branches	Main stem	Needles	Branches	Main stem
	(No.)	(lbs.)				(percent)		
COMPLETE TREE								
10	7	646	22	63	561	3	10	87
12	4	862	39	103	720	5	12	84
14	6	1,483	53	172	1,258	4	12	85
16	6	1,988	65	251	1,672	3	13	84
18	6	2,430	93	359	1,978	4	15	81
20	6	3,345	95	470	2,780	3	14	83
CROWN ONLY								
10	7	85	22	63	—	26	74	—
12	4	142	39	103	—	27	73	—
14	6	225	53	172	—	24	76	—
16	6	316	65	251	—	21	79	—
18	6	452	93	359	—	21	79	—
20	6	565	95	470	—	17	83	—

ranged from 646 pounds for a 10-inch tree to 3,345 pounds for a 20-inch tree. In 10-inch trees, 22 pounds were in needles, 63 pounds in branches, and 561 pounds in the main stem, compared to 95 pounds in needles, 470 pounds in branches, and 2,780 pounds in the main stem in 20-inch trees. Green weights of the various tree components can be calculated from the following average moisture-content values: stemwood, 108 percent; branchwood, 102 percent; stembark, 65 percent; branchbark, 115 percent; and needles, 105 percent.

The relative weights of stems, crowns, and branch materials vary with tree size (Table 4). This variability is associated to some extent with relative position of the trees in the canopy of uneven-age stands. The proportion of tree dry weight in crown materials increased with increasing tree size due to an increase in the proportion of large branches in larger trees. Needle weight as a proportion of total tree weight did not vary significantly with tree size and averaged only 3 to 5 percent.

Branches accounted for most of the crown weight—74 percent in small trees and 83 percent in large trees.

When needle weights were excluded, the proportion of total wood increased slightly (about 3 percentage points) as tree size increased. Ten-inch trees had 87 percent of their dry weight in wood and 13 percent in bark; 20-inch trees contained 90 percent wood and only 10 percent bark (Table 5).

Dry weights of the main stem varied with tree size in much the same way as did total-tree weights. In the main stem alone, the wood proportion ranged from 88 to 91 percent wood and bark proportion from 12 to 9 percent. The change with increasing tree size again was 3 percentage points.

The percentage of bark in branches was about twice as much as in the complete tree or the main stem. Branches in small trees had 24 percent bark, whereas those in the larger trees had 16 percent. Proportion of

Table 5. — AVERAGE OVENDRY WEIGHT AND PROPORTION OF WOOD AND BARK IN COMPLETE LOBLOLLY PINE TREES 10 TO 20 INCHES DBH AND TREE COMPONENT PARTS.

DBH class (in.)	Trees sampled	Weight			Proportion	
		Total	Wood	Bark	Wood	Bark
	(No.)	(lbs.)			percent	
COMPLETE TREE						
10	7	624	542	82	87	13
12	4	823	714	109	87	13
14	6	1,430	1,264	166	88	12
16	6	1,923	1,703	220	89	11
18	6	2,337	2,068	269	88	12
20	6	3,250	2,925	325	90	10
MAIN STEM						
10	7	561	494	67	88	12
12	4	720	636	84	88	12
14	6	1,258	1,123	135	89	11
16	6	1,672	1,501	171	90	10
18	6	1,978	1,778	200	90	10
20	6	2,780	2,529	251	91	9
BRANCHES ONLY						
10	7	63	48	15	76	24
12	4	103	78	25	76	24
14	6	172	141	31	82	18
16	6	251	202	49	80	20
18	6	359	290	69	81	19
20	6	470	396	74	84	16

wood in branches ranged from 76 percent in the small trees to 84 percent in the larger trees.

Biomass Removed by Logging

The proportion of wood removed in logging if the 35 sample trees were harvested to different merchantable limits is illustrated in Figure 1. In harvesting to a 6-inch top, the proportion of wood removed would increase with tree size up to 14 to 16 inches DBH, and then decrease as the trees became larger.

If saw logs and pulpwood to a 4- or 2-inch top were logged, the proportion of wood removed would decrease as tree size increased. Ninety-one percent of the dry wood in 10-inch trees would be removed when logging to a 2-inch top, whereas only 86 percent of wood in 20-inch trees would be removed. The decrease in proportion of wood removed as tree size increases is associated with the increase in amount of large branches. Tree-length logging to a 2-inch top, including all limbs 2.0 inches in diameter or larger, would remove 94 to 96 percent of all the wood in loblolly pines 10 to 20 inches DBH.

Estimated Biomass Left as Logging Residue

The data in Tables 4 and 5 and in Figure 1 clearly indicate that the main stem and branch components of the total tree vary with tree size. Thus, reasonably accurate estimates of logging residue for any natural, uneven-age stand require consideration of the sizes of the trees to be cut as well as the merchantable limit to which the stand will be harvested.

With the regression equations developed in this study, logging residue can be estimated before or after

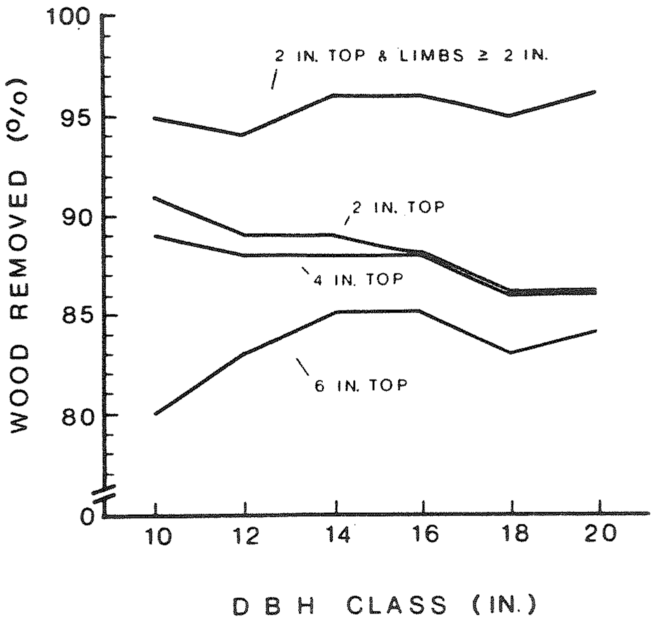

Figure 1. — Proportion of wood in loblolly pine sample trees removed by logging to various merchantable heights.

logging if data on stand composition are available. These equations permit estimates of residue in each crown component as well as totals. Such information is needed by anyone who is planning to use these materials.

To illustrate how logging to different merchantable limits affects weight and composition of logging residue in a natural, uneven-age stand, the regression equations developed were applied to 311 sale trees whose size and frequency distribution are shown in Table 2.

The total dry weight of these sale trees was estimated to be 385,928 pounds or about 193 tons. Based on the regression estimates, 85 percent (164 tons) of the total dry weight is wood, 11.6 percent (22.4 tons) is bark, and 3.4 percent (6.6 tons) is needles. When considering stem and crown portions of the sale trees separately, 75.6 percent of the sale dry weight is estimated to be stemwood, 9.4 percent branchwood, 9.2 percent stembark, and 2.4 percent branchbark. Table 6 shows estimated weights, compositions, and ratios of aboveground biomass logged and left when harvesting the timber to different merchantable limits.

If the timber sale were harvested to a 6-inch top, 82.9 percent of the 164 tons of wood in the sale would be removed from the forest for utilization. Approximately 526 pounds of dry logging residues would remain in the woods for every dry ton of wood and bark removed. The logged-to-residue ratio would be 3.8:1. Each ton logged would contain 89.3 percent wood and 10.7 percent bark. The composition of the logging residue would be 69.2 percent wood, 14.4 percent bark, and 16.4 percent needles.

Utilization to a 4-inch top would remove 87.8 percent, or 144 tons, of wood and reduce the amount of residue on site by 23 percent. Approximately 392 pounds of logging residue would remain in the forest for each dry ton logged. The logged-to-residue ratio would improve from 3.8:1 to 5.1:1. An additional 1.3 pounds of wood and bark would be removed from the site for every pound left as logging residue.

Harvesting to a 2-inch top would remove 89 percent, or 146 tons, of wood from the sale, leaving 11 percent of dry wood as residue. The logged-to-residue ratio would increase to 5.5:1. About 364 pounds of logging residue would remain in the woods for every ton of dry wood and bark removed.

Logging all stem material to a 2-inch top plus all limb material ≥2 inches in diameter would remove 95 percent, or 156 tons, of wood and increase the logged-to-residue ratio to 10:1. Each ton of wood and bark removed from the site for utilization would contain 89 percent wood and 11 percent bark. For every ton removed, 200 pounds of logging residue would remain in the woods. Only 45.3 percent of the residue would be wood, 16.8 percent bark, and 37.9 percent needles.

If each sale tree were harvested by the total tree concept, theoretically, all wood, bark, and needles in the sale (193 tons) would be utilized. Under this assumption, each dry ton utilized would contain 85 percent wood, 11.6 percent bark, and 3.4 percent needles.

Table 6. — ESTIMATED WEIGHT, COMPOSITION, AND RATIO OF BIOMASS LOGGED TO BIOMASS LEFT AS RESIDUE WHEN A LOBLOLLY SAWTIMBER SALE IS HARVESTED TO DIFFERENT MERCHANTABLE LIMITS.

Merchantable limit	Biomass logged				Biomass left as residue				Logged to residue ratio
	Dry weight	Composition			Dry weight	Composition			
		Wood	Bark	Needles		Wood	Bark	Needles	
	(tons)	- - - - (percent) - - - -			(tons)	- - - - - (percent) - - - - -			
6-in. DIB top	152.4	89.3	10.7	0	40.6	69.2	14.4	16.4	3.8:1
4-in. DIB top	161.6	89.3	10.7	0	31.4	63.3	15.6	21.1	5.1:1
2-in. DIB top	163.5	89.2	10.8	0	29.5	61.4	15.9	22.7	5.5:1
2-in. DIB top & limbs ≥2-in. DOB	175.4	89.0	11.0	0	17.6	45.3	16.8	37.9	10.0:1
Total tree	193.0	85.0	11.6	3.4	none[1]	0	0	0	....

[1]Assuming that no measurable residue would occur.